153rd Meeting of the Machine Protection Panel

Participants: M. Frankl, C. Hessler, E. B. Holzer, V. Kain, A. Lechner, B. Lindstrom, A. Perillo Marcone, Y. Nie, C. Schwick, G. Simone, J. Uythoven, M. Valette, G. Vandoni, C. Wiesner, D. Wollmann.

The slides of all presentations can be found on the website of the Machine Protection Panel:
http://lhc-mpwg.web.cern.ch/lhc-mpwg/

1.1 Approval of MPP#152's minutes

- Actions from the 152th MPP:
    - TE-ABT, Collimation: Verify the phase advances from the MKDs to the TCPs and how many bunches can escape the TCDQ if injected the abort gap.
        - Studies are ongoing and will include the evaluation of the damage limits of the roman pots.

1.2 Status and results of TDE material damage studies (A. Perillo Marcone)

- Antonio presented a summary of the experimental results of oxidation of dump material in air at high temperatures. The assumptions made in the past were taken from laser induced heating experiments, which were too conservative, most of the damage actually came from thermomechanical stress due to the localized heat deposition.
- New experiments in which the samples were heated to 850 ^{o}C in a furnace and exposed to air for 100 seconds show no apparent change in microstructure or any sign of oxidation. Further experiments with temperatures reaching 1100 ^{o}C are under way. In parallel, tests were performed by SGL, the manufacturer, where the samples were heated to 2500 ^{o}C and exposed to air for ten seconds. This experiment showed a mass loss of up to 1 %. The damage seemed to be limited to the material surface as the temperature is too high for the oxygen to diffuse in the bulk.
    - Daniel asked if oxidation could happen inside the material, Antonio answered it could happen in longer timescales and with large quantities of oxygen, which is not representative of the situation in the TDE.
- The latest set of experiments were performed by SGL on one of the two materials used for the dump: Sigrafine. In this test, a sample is heated to 1200 ^{o}C then exposed to air for 100 or 1000 seconds before cooling down in an inert atmosphere again. This test is supposed to model the effect of ~100 dumps in air. The mechanical properties of the samples were measured and showed a mass loss of 1 and 4 % for expositions of 100, respectively 1000 seconds, which is consistent with the literature and the previous experiments. After 1000 seconds of exposure, holes could be identified on

the surface. No change in density (outside of the holes), electrical resistivity or dynamic modulus were observed.

- As a general conclusion, Antonio excluded the possibility of igniting the dump at high temperature in air. A comprehensive set of data regarding all the experiments is to be released in the beginning of 2018. For further investigation, a real test with beam (e.g. in HiRadMat) could be envisaged.
  - Jan commented it is good that no runaway heating due to oxidation was observed. He suggested we keep the dump operating in Nitrogen but operating in air can be tolerated as a degraded mode for short durations. Daniel responded that it is possible that the graphite is oxidized away dump after dump and could degrade its mechanical properties. The question would then be: can a slow degradation of the dump be detected? This topic is covered in Jan's presentation.
  - Antonio reminded that the dump was initially conceived to be operated in vacuum (1e-5 mbar) based on the assumption that a single dump with the TDE in air would have catastrophic consequences, we now have experimental evidence of the opposite. He added that some developments are currently ongoing to avoid leaks occurring in the TDE for the HL-LHC upgrade.

1.3 Temperatures in the TDE core for 2017 beams (M. Frankl)

- Matthias presented an overview of different filling schemes relevant for 2017 operation, the failure cases considered in case of a dump and the resulting peak temperatures in the TDE core. Beam parameters include BCMS beams with 1.2e11 protons per bunch and 1.4 µm transverse emittances even though the dump temperature depends only weakly on the beam emittance. The two reference scenarios studies are a regular MKB sweep and the failure of two dilution kickers.
- The worst filling scheme is the 2556 bunches with 25 ns spacing, the resulting hotspot temperatures are ~1000 ^{0}C and ~1500 ^{0}C for a regular dump and a double MKB failure scenario, respectively. The temperature at the surface of the second block made from low-density carbon is 20% lower than the peak temperature in the previous block, 2.8 m deep from the front face. Transversally, the hotspot is located at the change of direction of the vertical kickers, where the sweep velocity is the lowest. The surface temperature of the dump in the worst-case scenario is 1200 ^{0}C, which served as input for the studies presented before. The highest surface temperature of carbon with 8b4e beams is less than 1000 ^{0}C for 8b4e beams and 1916b.
  - Daniel asked about the accuracy of these simulations. Matthias answered that there is a 10 % margin in energy deposition which translates into a 15 % error in temperature change coming from uncertainties in densities and specific heats. Anton added they usually give higher error margins in these simulations, but in this case it is only coming from the simulation of longitudinal shower development. Matthias commented that these estimates are on the conservative side from the FEM simulations.

  - Jan observed that the hotspot temperature could reach 1500 °C (in case of a worst-case dilution kicker failure), a temperature at which the previous talk suggests there could be mass loss. Daniel added that if there is a reduction of the density, the hotspot would move deeper into the bloc, thus, closer to the exit face, leading to higher surface temperatures, accelerating this phenomenon. Jan concluded one would need the dump to be in Nitrogen with 2556 bunches in the machine, and that something should be done in the YETS.
  - Anton commented that a kicker failure of this severity never happened in the past and would require serious malfunction of the MKBs.
  - C. Schwick asked what the current situation of the dump was. Daniel answered the current assumption is that the dump is under nitrogen but with ambient pressure. The topic is further developed in Jan's talk.

1.4 Available diagnostics to detect further degradation of the TDE (J. Uythoven)

- Jan summarized the diagnostics available in the dump cavern and how they could be used to measure potential degradation of the TDE. There are currently BLMs (downstream of the dump behind the shielding), radiation monitors in the cavern and for the extracted air, as well as pressure gauges close to dump volume and on the nitrogen line from the bottle.
- Monitoring the data recorded in the past months shows we have had no overpressure on the B2 dump since September 1st , despite the installed rack of 6 N2 bottles. However, the pressure in the dump does not give any information on the status of the dump itself. The BLMs could provide such an information but have had problems lately. The few dumps that were recorded properly since September the 1st suggest there is no degradation.
  - Daniel commented that some extra BLMs will be installed outside of the TDE shielding during the coming YETS (see MPP#151).
- The RP measurements also show a good overlap of the levels from similar monitors on the B1 and B2 dumps, which is also true for the detectors monitoring the extracted air.
  - Daniel observed there seems to be lower radiation from both dumps than in the October 2016 data which was used as a reference.
- Jan concluded that although the diagnostics there are limited, no anomalies are observed and the dump appears to be in a good state. This data should be reviewed again in a few weeks and after each dilution failure. Also, fixing the IC BLM behind the dump should be a priority.
  - Antonio added that some additional instrumentation will be installed in the YETS, e.g. some optic fibre based strain gauges to measure mechanical stresses in the dump window. Simone commented that EN-STI will try to keep the changes simple for the YETS 2018 and prepare a detailed plan for LS2 and the post-LS2 operation. Barbara asked for more details about the fibre based strain gauges as there are some ideas for such concepts for BLMs. The strain gauge work by

measuring path differences but they are not radiation tolerant and are just a mid-term solution for 2018.

1.5 SPS CC: Final plan for interlocking of crab cavities in SPS (G. Vandoni)

- Giovanna first recalled the layout of the crab cavities (CCs) installation in the SPS tunnel and in the surface area. The cavities will be in a cryomodule on a moving table. Issues such as Oxygen Deficiency Hazard from the use of liquid Helium are not described here but have been taken into account for personal safety, which was all done with EIS standards. For example, access in the sector provides a veto for RF and table movement if there is helium.
    - Daniel asked where the override key would be for this system. There will be one locally in the tunnel, one in BA6 and one in the control room, but only one of the keys can be piloting the table. This is required for the commissioning of the table movement etc.
- The CC machine protection system needs to be flexible as there will be a lot of learning from the system in the commissioning phase and during the running in the SPS in 2018. As the CCs will be an aperture bottleneck in the ring, the presence and extraction of beam to the LHC will be interlocked versus the table position and movement. For the protection of the CCs themselves the RF power will be interlocked versus cryogenics. The vacuum and the beam presence will be interlocked to HOM power from the cavity being below 200W to protect the LHC type coupler feedthroughs, even in transparent operation when the cavities are not powered.
- The test plan will be presented at the HL-TCC next week and the main idea is to keep flexibility via a mostly software interlock. One maskable and one un-maskable interlock will be added to the SPS ring BIC and to the SPS extraction BICs. The software permit from Operation would be unmaskable as well as the so-called 'Verena interlock', which will require the operator to acknowledge that the CCs are in the beam. The BLM at the CC position will have an individual interlock setting from the software. Regarding RF, protection from the IOTs, RF services and signal will be concentrated in an RF_SAFE flag. The relevant documents such as the ECR for the access system and the interlocks functional specifications (EDMS 1843638) are being prepared, the deadline for the whole system to be ready for operation is March 2018.
- Giovanna concluded that the interlocking is robust as per CERN standards and flexible from being software based. There should be no problems related to activation of material near the CCs due to the limited MD time and beam intensities.
    - Jan commented that for slow effects such as vacuum, power and thermomechanical effects a software interlock is suitable but for everything beam related a hardware interlock via a CIBU with custom logic is more suitable. He added that the readiness of the CIBUs will be checked when the ECR documents are ready, i.e. next week.
    - Daniel made the observation that basing the local BLM threshold on experience is not the usual procedure, which implies defining failure cases and associated loss levels to protect against a predefined

scenario. Giovanna answered that the threshold will be initially set to the same level as the neighboring ring BLMs and will be lowered following tests with safe beams.